

WHAT IS THE NATURE
OF THE DEVELOPMENT
OF KINETIC IMAGERY?

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Master of Arts in Psychology
in the
University of Canterbury
by
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University of Canterbury
1978.

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ABSTRACT

1.

Young children's ability to represent movement in imagery was investigated involving the presentation of pairs of 2-dimensional stimuli either in the same orientation, or differing by a clockwise rotation of one member to various positions up to 180° . These stimuli were either identical or they differed by a rotation of the internal structure about the horizontal axis. Children were required to judge if the two stimuli were same or different. Reaction times increasing as a linear function of angular discrepancy between stimuli were taken as an indication of mental rotation. Generally mental rotation was exhibited by 20 5-year olds but not by 20 4-year olds using stimuli that appeared as solid figures. Numbers of those displaying mental rotation increased with decreasing angular separation of the stimuli. Twenty-eight 5-year olds tested using outline drawings of the stimuli, and twenty 5-year olds using stimuli with a more complex internal structure did not exhibit mental rotation. Results were interpreted as indicating that kinetic imagery develops gradually and that the rate of development interacts with that of certain perceptual variables. These results conflict with Piaget and Inhelder's notion that imagery representing movement first emerges when children are 7 to 8 years of age.

The relevance of kinetic imagery (which is imagery representing movement) to creative thought has been strongly emphasized in Cooper and Shepard (1973, p.171) and in Shepard (1978). Also the nature of this phenomenon has become an important issue in contemporary cognitive psychology, mainly through the work of Shepard and his associates (e.g. Cooper, 1975; Cooper & Shepard, 1973; Metzler & Shepard, 1971; Shepard, 1975; 1978; Shepard & Chipman, 1970; Shepard & Metzler, 1974) who restricted themselves to adult populations. Apart from the results of a few studies directly concerned with the testing of various implications of Piaget and Inhelder's (1971) stage theory of development and mostly using Piagetian methodology, little is known regarding the development of kinetic imagery. Thus the purpose of the present study is to investigate the development of kinetic imagery in young children in a manner which is less bound to Piagetian conceptions and using a method adapted from the Shepard studies.

PIAGET'S STAGE THEORY AND THE
ASSOCIATED LITERATURE.

Although Piaget's stage theory has generally dominated the developmental-cognitive field, it faces opposition by some researchers. For example McCall, Eichorn and Hogarty (1977) pointed out that Piaget has ignored the entire realm of individual differences. They believe that greater attempts should be made to consider integrating changes in both individual and group data across stages, and to incorporate these within general theoretical orientations.

Similarly, Ginsburg and Koslowski (1976) hold the view that progress will be made when investigators explore naturalistic techniques for the study of development; and when they become less concerned with the study of Piaget's theory and more interested in the phenomenon of development per se.

However, Piaget's theory has generated virtually all research associated with the development of kinetic imagery and although the above critics' "purer" alternative to the study of development is appealing, the practical problems involved would be immense; particularly using such presumably inaccessible cognitive variables as "imagery".

Piaget's theory implies distinct or qualitative differences in children's modes of thinking or solving the same problem, forming a universal sequence of development. Each mode of thought forms a structural whole and stages form an order of increasingly differentiated and integrated structures. As a result one should observe instances of cross task correlations within a stage as well as *décalage*. Piaget's concept of *décalage* refers to an individual's operating at different cognitive states at different times or in different realms. While the claim of structural wholeness refers to a common structure that can be used to analyze the child's reasoning across a range of categories of experience, it does not mean that a given child functions at a certain stage across all experiences, i.e. it refers to a general state. Thus the child's thinking may vary across adjacent stages or tasks of greater or lesser difficulty (Selman, 1975).

Piaget has postulated two levels of cognitive thought, namely operational and preoperational thought.

Operational thought is in evidence around 7 to 8 years of age in Western type societies. Thought at this level can deal with data that is intuitible i.e. perceptible or imageable; and permits transformations on reality by means of interiorized actions (Lovell, 1972). The major difference between preoperative and operative knowing is that the source of the former is

the outside world whereas the source of the latter is the child's own activity on the outside world; it is deductive (Furth, 1977).

Piaget and Inhelder's Concept of the Development of Imagery

Piaget and Inhelder (1971) distinguished between two different classes of imagery which typify the two levels of cognitive thought. The following passage from "Mental Imagery in the Child" illustrates their position:

In short, the two main periods of image development correspond to the preoperational (before 7 to 8 years) and the operational levels ... the images of the first period remain essentially static and consequently unable to represent even the results of movements or transformations and a fortiori unable to anticipate processes not yet known. But at about 7 to 8 years a capacity for imaginal anticipation makes its first appearance, enabling the subjects to reconstitute kinetic and transformation processes, and even foresee other simple sequences (Piaget & Inhelder, 1971, p.358).

According to Piaget and Inhelder the pre-operational child tends to focus on stationary objects (Piaget & Inhelder, 1971, p.359) but when he does focus on the motion of objects he tends not to comprehend that the parts of the moving object change position in a co-ordinated fashion, (Piaget & Inhelder, 1971, p.120). Moreover, in imagining a moving object, the preoperational child may distort one or more of its properties (Piaget & Inhelder, 1971, p.360).

Emperical Tests of Piaget and Inhelder's Theory. 6.

Experiments testing Piaget and Inhelder's theory of the development of imagery are generally designed to test the prediction that the number of subjects producing correct judgements on kinetic imagery tasks would increase as a function of increasingly advanced cognitive structures (i.e. those permitting operational reasoning). For instance researchers have compared performance on kinetic imagery tasks with that on conservation tasks which are claimed to be indicative of the development of operational thought (Piaget & Inhelder, 1971, chap.8).

A second prediction, that kinetic imagery first emerges when children are 7 to 8 years old, is also indirectly tested using this design.

In general, conflicting results have been found. For example, the results of Oppenheimer and Strauss (1975) contradicted both predictions while those of Madden (1975) lent support to both. However, closer examination reveals that operational reasoning was assessed through discontinuous quality and length conservation in Oppenheimer and Strauss' study, whereas in the work of Madden, it was assessed through conservation of number and of continuous solid amount. Similarly the tasks assessing kinetic imagery development differed between experiments. Oppenheimer and

Strauss' task involved the anticipation of the end states of a rotated rod. Madden's task required subjects to anticipate a translation of one of two identical squares from directly above, to the right, for a distance one half the width of the other.

Thus it may be argued that differences arose due to varying task difficulty of either the conservation or the kinetic imagery tests i.e. *décalage*. However the large time gap (2 to 3 years) between the observed development of the two concepts in Oppenheimer and Strauss' study casts doubt on the notion of common underlying structures.

Piaget and Inhelder (1971, chaps. 3 & 4) directly tested the prediction that kinetic imagery first appears at 7 to 8 years of age using various types of kinetic imagery tasks. These included gestural imitation of the trajectory of two fixed points on a rod rotated through 90° ; rotation and overturning of square figures; anticipation of the positions of six elements on a rotating disc as well as tasks closely similar to those of Oppenheimer and Strauss, and Madden. With the exception of two sets of results (Piaget & Inhelder, 1971, p.65-73, and p.135-144) findings supported their prediction of the emergence of kinetic imagery around 7 to 8 years. In the latter study Piaget and Inhelder found that 5 year olds could not properly draw the trajectory of a beaded rod in rotation, but could accurately portray

the beginning and end states of rotation. Similarly the former study showed that some 4 and 5 year olds successfully drew the initial and final positions of a pivoting rod, but could not draw its trajectory. Piaget and Inhelder concluded that 5 year olds could, at least sometimes, imaginally represent the outcome of a rotation without being able to imaginally represent movement itself (Piaget & Inhelder 1971, p.83, 137). Further, as an explanation for this they suggested that the observed solutions for the tasks were based on reproductive imagery of previously encountered events, similar to the tasks used in the imagery problems.

Oppenheimer (1976) attempted to test this argument. In order to do this he presented preoperational and operational subjects with stage assessment tasks before a combined dynamic imagery and conservation task (ICT). The former consisted of discontinuous quality and length conservation tasks. The latter involved the anticipation of the end positions of two sticks, known to be equal in length, when placed in a box with the other ends protruding different lengths. Also the subject was questioned as to how the sticks were to be made equal again. Within the length conservation tasks one was very similar in display to the length conservation task in the ICT and consequently, to imagery problems in the ICT.

A second sample of preoperational and operational children were presented with both tasks in the reverse order. Oppenheimer reasoned from Piaget and Inhelder's theory that performance by preoperational and operational subjects on both dynamic imagery tasks will be better in the assessment - ICT order than the ICT - assessment order. That is in the former order this will be a result of the availability of reproductive imagery, while in the latter order the subjects can only solve the task by means of dynamic imagery, which, according to Piaget and Inhelder, will be difficult, if not impossible, for the preoperational subjects.

The results did not support Piaget and Inhelder's viewpoint. Although Oppenheimer did not control for past experience he reasoned that the chances of all the high percentage of successful subjects previously encountering similar events "seems small".

Secondly, it may be argued that there could have been a lack of emphasis on movement which would have led to a non dynamic character of the imagery tasks. However, Oppenheimer states that his tasks require only dynamic imagery to solve them.

Finally an explanation for the results could be that the questions posed to the subjects referred to qualitative end state changes and not to metric quantitative changes. Oppenheimer admits that the experiment does not refute this possibility except for

10.
the fact that a very high proportion of the pre-
operational children solved the tasks.

On the whole Oppenheimer's experiments are suggestive but cannot be taken to offer conclusive evidence against Piaget and Inhelder's account.

Support for Piaget was lent by De Lisi, Locker and Youniss (1976). In this study the child was required to mimic the experimenter's movements of a toy car around a board with his own car and board. Level of performance was found to increase with age. Also the age at which kinetic imagery was first evident was consistent with Piaget and Inhelder's estimate.

A Methodological Weakness.

It could be argued that response measures such as drawing, gesturing and verbalization may bias results in favour of the older children. All researchers mentioned have depended solely upon these response measures. Specifically, Piaget and Inhelder (1971) relied heavily upon both drawing and gesturing, whereas De Lisi et.al (1976) relied upon gesturing and Madden (1975) relied primarily upon drawing. Oppenheimer's studies (1975, 1976) used a multitude of response measures : drawing, gesturing and verbal explanations of these, all of which could lead to confusion between performance and competence (Marmor, 1975). Moreover the findings of Oppenheimer

and Strauss (1975) indicated that these performance measures developed at different rates and differentially at various operational levels. This finding complicates any attempt to interrelate the literature.

THE SHEPARD PARADIGM

Two studies that do avoid confounding performance effect with competence are those of Marmor (1975) and Wallace (1978). They achieved this by the use of the Shepard paradigm. This technique was devised by Shepard and his associates (Shepard & Metzler, 1971; Cooper & Shepard, 1973) to indicate the use of kinetic imagery, specifically kinetic imagery of rotation. Basically it involves the presentation of pairs of pictures of geometrical forms which may differ in orientation. One form remains upright while the other is tilted to various orientation positions from 0° to 180° differing from trial to trial. Also members of pairs of forms may be identical or mirror images of each other. Thus the subject's task for each trial is to decide whether the two forms are identical or mirror images. The finding that response time is a linear increasing function of the angular difference between members of each pair of stimuli is taken as evidence that subjects mentally rotate an image of one member of the pair into congruence with the other member.

Thus using this method a choice response measure is employed.

Marmor (1975).

Marmor used two dimensional bear shapes as stimuli in place of the geometrical forms. One arm of each bear was raised; identical pairs consisted of two bears with the same upper arm raised while mirror image pairs consisted of pairs in which different arms were raised. Results of 5 year old children yielded positive linear response time vs degrees of rotation functions which were interpreted as indicating kinetic imagery at this age level. However, other work (Corballis & Beale, 1976) suggests that children at this age may have difficulty in discriminating left and right reversals of the same form.

The Development of Left and Right

Corballis and Beale (1976) concluded from a review of the literature that by the age of 6 years most children can reliably differentiate between left and right parts of their own bodies, but performance on other items continues to improve up to the age of 10. Moreover, Davidson (1935) (cited in Vurpillot, 1976) estimated mirror image confusions occurring up to a mental age of 7.5 years. Therefore it is surprising that Marmor achieved positive results for 5 year olds.

However, results of a study by Bijour and Baer (1963) (cited in Vurpillot, 1976) showed that by intensive training, mirror image confusions between geometric forms could be reduced to less than 10% in 3 year olds. This suggests that Marmor's results may be explained by her pre-experimental training sessions.

Motor Manipulations of the Stimuli.

Marmor's procedure involved an extensive pre-training period in which the child manually rotated the experimental stimuli. Subjects were also required to pass a criterion test before experimentation. The fact that 23% of the 5 year olds failed to reach criterion was disregarded by Marmor in drawing conclusions.

Although Marmor suggested that the differences in results between her work and that of Piaget and Inhelder (1971) may be due to differing instructions, she had not ruled out the possible effects of motor manipulations. Indeed, the work of Varley, Levin, Severson and Wolff (1974) points to motor manipulations as being a major factor causing the difference between the two sets of results. These researchers confirmed the results of a study by Wolff and Levin (1972) which demonstrated that 6 and 7 year olds did not benefit from instructions to imagine an interaction between pairs of toys in a memory task but when they were permitted to play with toys, concurrently

their recall improved dramatically. This result was interpreted as being consistent with Piaget's (1962) theory of cognitive development in which it is assumed that the preoperational child cannot produce dynamic visual representations (internally) without motor activity involving the events to be represented.

Varley et.al (1974) investigated differences in performance of younger and older children within Piaget and Inhelder's (1971) imagery transition stage. The results showed a significant performance difference between children participating in the motor training group and those in the motor control group for preoperational children only.

Wallace (1978).

Wallace (1978) also employed the Shepard paradigm but avoided the possible confounding effects of the development of left and right. Only a dissertation abstract of this paper became available subsequent to data collection of the present study; thus a full analysis of the work was impossible. However, an attempt will be made to discuss this work since the experimental procedure is similar to that of the present study.

In Wallace's experiment thirty-six children aged 4 to 9 years participated (presumably six of each age group). Stimuli consisted of both asymmetrical and symmetrical pairs of letter-like forms. Wallace also adopted Shepard's notion that a linear effect of

angular discrepancy between members of pairs on 15. latency of responses was indicative of an isomorphic analog representation of imagery. The main purpose of the study was to test the Piagetian prediction that kinetic imagery depends on the establishment of operational thought defined by the ability to conserve liquid. In addition to being tested for the ability to rotate, subjects were also tested for the ability to consciously differentiate mirror reversals.

Mental rotation occurred for both conservers and nonconservers and for both those capable and incapable of differentiating mirror reversals. These results were interpreted as evidence that rotation was tied to non-conscious processing, non-conscious analog representation of motion and space. This interpretation was based on the premise that nonconservers could not use analog representation in consciousness. From this it was assumed that analog representation was present in both conservers and nonconservers in non-conscious processing, but only in conservers in conscious processing. Although the Piagetian prediction to be tested was not supported, results were still interpreted as supporting Piaget's theory i.e. as an example of *décalage*. Specifically, analog imagery was interpreted as being constructed in consciousness increasingly well as comprehension of space developed.

It was also assumed that asymmetrical pairs of stimuli required wholistic comparison while symmetrical pairs only required feature comparison. Only the asymmetrical objects were found to be rotated which was taken to suggest that the symmetrical pairs were differentiated with topological mediating representatives. In a separate experiment eleven adults were found to rotate symmetrical pairs. This was taken as indicating that the adults did not use topological representation and therefore implied that the adults had further developed procedures for constructing analog imagery.

Overall, the results were interpreted as supportive of Piaget in that imagery is constructed from unconscious knowledge of Euclidean space and motion, and that this construction depends on achievement of operational thought. A difference between these conclusions and Piagetian theory is that here the unconscious knowledge of space is a form of representation whereas to Piaget it is cognitive comprehension of space itself.

The implications of the theories on which Wallace's work is based have not been supported by the literature. For example Shepard's notion that the linear function of the Shepard paradigm is indicative of an isomorphic analog representation of imagery has been seriously undermined by a recent analysis by

Anderson (1978). In this paper Anderson argues that rotated images need not be represented in the above manner. Thus Wallace's differentiation between isomorphic analog representation and topological representation rests only on the assumption that Shepard is correct.

Similarly, arguments based on an assumption were used as support for Piaget and Inhelder's theory i.e. Wallace assumed that kinetic imagery by children who could not conserve liquid was unconscious and that kinetic imagery demonstrated by children who could conserve liquid was conscious. On the contrary, conscious ability in one cognitive skill does not necessarily mean conscious ability in another. Indeed the work of Annoshian and Carlson (1973) implied separate developmental processes for conservation tasks (including conservation of liquid) and static and kinetic imagery. Conservation (probably because it requires deductive reasoning) correlated significantly with intelligence, while kinetic and static imagery correlated significantly with chronological age.

In sum Wallace's work may meet difficulties due to the research method and interpretations being closely bound to theory.

OUTLINE OF THE PRESENT EXPERIMENT

For the present experiment the Shepard paradigm was employed except "different" pairs of stimuli differed by rotations up to 180° around the horizontal rather than the vertical axis. This method was employed since adaptation to the physical world involves the recognition of the upper as opposed to lower parts of those objects with a standard up and down (Vurpillot, 1976, p.78) and requires this skill to develop in late infancy (Church, 1970).

Stimuli consisted of both an internal and external structure to avoid the possibility of an overly simple task producing little variation in response times with orientation. Also the external structure was intended to discourage feature comparison of the static figures.

In addition, the present experiment aimed to compare levels of performance of different age groups at each angular difference between stimuli as scaling responses in a quantitative manner permits distinctions that all or none categories may mask.

Finally motor manipulation by the child was not involved. Evidence of kinetic imagery in 5 year olds in the absence of motor manipulations of the stimuli would contradict Piaget and Inhelder's claim that operational thought is not possible at this age level.

Stimuli and Task

A second consideration involves the nature of the stimulus and the relative difficulty of the task.

Cooper (1975) and Cooper and Podgorny (1976) found no differences in reaction times with complexity of the stimuli for adult subjects. (The number of angles or points determining inflexions on the perimeter of the stimulus form was used as an index of complexity). This finding has been used as evidence supporting Shepard's notion that images are represented in an isomorphic analog form (Cooper & Shepard, 1973; Shepard, 1975, 1978). However this argument has been attacked by Anderson (1978). In addition the work of Chipman and Mendelson (1975) indicated that differences in complexity may affect children's performance on kinetic imagery tasks. These researchers showed that sensitivity to visual structure may develop well into school age, taking the form of a gradual increase in the number of pattern elements which can be perceived to be organised. The present study attempted to test this, using three sets of stimuli, each differing in complexity as defined by Cooper (1975).

To test the relative strength of the child's ability to manipulate images certain trials were designed to tempt the child to abandon mental rotation of the whole figure and resort to comparison of static internal structures.

Sex Differences

Finally, since performance on kinetic imagery tasks was found to vary with judgements about Euclidean spatial relations (Dean, 1976) and mental testing literature reveals a consistent sex difference in spatial skills in favour of boys (Anastasi, 1958) the present study also attempts to investigate the possibility of sex differences.

EXPERIMENTAL METHOD AND RESULTSEXPERIMENT I

Experiment 1 was a pilot study carried out to determine the approximate lower age limit of children who could understand the instructions and solve the type of problem to be employed. It also served to clarify the procedure.

Subjects

Three age groups of children, randomly sampled from Fendalton Kindergarten and Ilam School, participated in this experiment. These were : six school children with an approximate mean age of 5.75 years, four "new entrants" to primary school (aged 5.0 years) and seven kindergarten children with an approximate mean age of 4.75 years.

Stimuli

Stimuli consisted of individual two dimensional milk bottle shapes, 6.5cm in height, cut from thick cream coloured writing paper. Each shape displayed a black solid colour star in a position usually occupied by the label on a bottle. Also three types of star were used (3-, 4-, and 5- point) each generating a set of three stimuli (the sets hereafter are referred to as stimulus A, B and C respectively). Each set consisted of two identical forms known as the "standard" and the "identical" forms, and one other which differed by a

rotation of the star around the horizontal axis, known as the "different" form. These are illustrated in Figure 1.

Procedure

Each child was tested individually in a quiet room at the school or kindergarten. The experiment was introduced as "a game with labelled milk bottles". Each child was first shown an upright set of stimuli (one "standard," one "identical" and one "different" form). He was asked to identify the different form and to explain his choice. If this was correctly identified the child was shown an upright pair chosen from the set and was required to say "same" or "different". When these responses were established for the appropriate pairs, other pairs consisting of one upright "standard" form and one rotated "identical" or "different" form were introduced with the following instructions : "One of the milk bottles might be tipped up. Can you still see if it is the same or different to the one standing up?" The orientation positions of the "different" or "identical" forms were approximately 0° , 45° , 90° , 135° and 180° clockwise rotations from upright. The "standard" form always remained upright.

"Confusion" trials occurred when the internal structure of the rotated stimulus was exactly the same orientation as that of an upright form but when rotated

back to upright it was identical to the orientation of the other figure. For example when the "identical" form of stimulus B was rotated to 45° and 135° its label resembled that of the upright "different" form and vice-versa. This is illustrated in Figure 2 where the internal forms in (ii) and (iii) are at the same orientation although in their upright position they constitute different forms relative to the base objects. The same is true of (i) and (iv). For stimulus A confusion trials occurred at 180° rotation (see Figure 3). Because of the particular angles of rotation employed, there were no "confusion" trials for stimulus C.

If children did merely compare internal structures regardless of orientation of the bottle shapes a high error rate would be expected at 45° and 135° for stimulus B and at 180° for stimulus A. Conversely, for rotation positions 90° and 180° for stimulus B, the internal structure was the same as that for the correct upright form. Thus a high success rate was expected if children were comparing internal structures only.

Practice trials at each of the orientations 0° , 45° , 90° , 135° , and 180° were given as was necessary to familiarize subjects with the procedure. This resulted in their completing a total of about 10 trials. For each trial the child viewed the pairs of

stimuli after they had been put in a position on a flat wooden surface. After the child's response the experimenter checked their response by picking up the rotated form and placing it upright next to the "standard" form. However, this practice tended to confuse the children so it was abandoned. Manual rotation to check the child's answer was subsequently performed by the experimenter (in view of the child). On no occasion was the child allowed to manually rotate the stimuli himself. The child was given knowledge of accuracy of results after each response.

For the experimental trials, orientations were presented in the order of 45° , 135° , 90° , 180° . "Same" and "different" trials for each orientation were assigned randomly to two different trial blocks. One block of trials consisted of one "same" or "different" trial for each orientation, while the other block consisted of the complementary trial for each orientation. The child was given both blocks of trials for each stimulus and in some cases a replication was given.

Results and Discussion

Results are summarized in Table 1. Children aged approximately 5.75 years appear to cope better with all stimuli than the younger children. The performance of children in the 5.0 year and 4.75 year age groups appears to be indistinguishable and, since the novelty of the school experience may have impeded the

performance of the new entrants, children of this age group were not used in later experiments.

While all children correctly identified "same" and "different" upright pairs for each stimulus, performance varied with angular differences between forms, stimulus and age. Moreover it appears that only children aged approximately 5.75 years can adequately solve this type of problem, and only for stimulus A. For all other age groups and stimuli, adequate performance over the entire range of angular separations between forms was not possible. Results also indicate that the performance of younger children becomes unreliable for rotations greater than 90° .

Children of all age groups appear to be unable to resist the "confusion" trials with stimulus B. Thus it seems that the children were tempted to abandon mental manipulations of images and merely compared the internal structures, ignoring the orientation of the external structures. The exceptionally low error rate for the 90° and 180° positions is consistent with this interpretation. Similarly, for stimulus A the very high percentage of errors for the 180° position for the younger age groups may be due to a comparison of internal structures exclusive of external forms.

Verification of these results is sought in subsequent experiments using response time measures and affording greater control over the mode of stimulus presentation.

EXPERIMENT 2

This experiment used outline drawings of the bottle shaped forms used in Experiment 1.

Subjects

Twenty-eight children (14 of each sex) with an age range of 5.5 to 6.0 years and a mean age of 5.81 years participated in this experiment. All children were from a single classroom at Ilam School, Christchurch.

Apparatus and Stimuli

Pairs of black outline drawings of two bottles bearing the star labels of Experiment 1 were drawn on white cards measuring 101 x 151mm. The bottles were 90mm high. Each card depicted one upright "standard" bottle and an "identical" or "different" bottle in an upright position or at 45°, 90°, 135° or 180° clockwise rotations from upright. While the bottles were in the form of outline drawings, the labels consisted of areas of solid black. Thus with three stimuli, five angles of rotation and identical and different pairs a total of $3 \times 5 \times 2 = 30$ stimulus cards were required for a single replication of all conditions. Cards were represented in sets, each set comprising the cards for one stimulus type.

The cards were viewed through a Amref. tachistoscopic viewer (No. 10AB/155) (to eliminate head turning) attached to a specially constructed illumination unit mounted on a Hampton Middy card changer (model J.N. 499). The illumination unit consisted of a light resistant box of matt black interior with a one-way vision screen, and small incandescent luminaires arranged so that when lighted the cards were adequately and evenly illuminated without glare. Cards were not visible when the lights were extinguished.

The experimenter initiated trials by depressing a switch which emitted a clearly audible click serving to inform the subject that a trial was about to commence. Half a second later (the time was determined by a Lafayette interval timer, model 50011) the stimulus was illuminated and remained so until a vocal response, detected by a Lafayette Voice Activated Relay (model 6602A), was made and the lights extinguished. Depression of a second switch by the experimenter changed the card. Also, response time was recorded by means of a Lafayette clock/counter (model 54417) which began timing with the onset of illumination of the card and stopped when a vocal response was detected.

Children were tested individually in a quiet room at the school and sessions lasted approximately 30 minutes. The experiment was introduced as in Experiment 1. The child was given at least one block of practice trials (i.e. one trial at each orientation position) using the stimuli of Experiment 1. Throughout this experiment the five orientation conditions were randomly ordered with the following restrictions:

- 1) Each orientation proceeded every other an equal number of times (i.e. using a series of blocks of trials).
- 2) A given orientation condition was never presented consecutively (i.e. at the end of one block and at the beginning of another).
- 3) Same or different pairs were never presented more than three times consecutively.
- 4) Single and double alternation sequences of identical and different pairs were limited to three consecutive alternations.

The child's responses were corrected as in Experiment 1. If the child's responses were found to be consistently wrong, he was asked to explain his

choice. This eliminated a certain amount of misinterpretation of the instructions (e.g. the child may be only comparing labels or using some degree of orientation as the cut off point between "same" and "different" stimuli). In the case of misinterpretation the task was re-explained more slowly. The experimenter demonstrated correct responses to a few trials and checked them as above. If the child persisted in responding wrongly the process was repeated and he was further encouraged to verbalize his understanding of the task. All children appeared to understand the task.

For the experimental trials the child was instructed to answer both quickly and accurately in the following way: "I want you to try very hard to give the right answer. When you are right I will know and mark it down. If you are right enough times you may win a prize at the end. You must also answer as fast as you can. You cannot win a prize if you do not answer fast enough". One practice block of trials using Stimulus A was given using the experimental apparatus. Each child was then given two complementary blocks of trials with Stimulus A

and if the child was willing to co-operate further, a replication of the 10 trials was given. A two minute break was allowed between blocks of trials.

Two blocks of complementary trials, and in some cases a replication followed with Stimulus B and Stimulus C for nine subjects who approached error free levels with Stimulus A.

Throughout the experiment the child was reminded from time to time (as was felt necessary) to answer as quickly as possible but not to guess. Knowledge of accuracy of results was given after each response and knowledge of prompt responses was given intermittently (again as was felt necessary).

After the experiment was completed all children who participated received a small prize (a tiny packet of sweets).

Results

Percentages of errors for stimulus A, B and C at each orientation are given in Table 2. A criterion of at least three correct of four trials (or two correct of two, for subjects receiving only two blocks of trials) was used to indicate accurate performance. Correct response times from identical and different trials were pooled because of the small number of trials and visual examination of the data suggested response times in the two conditions to be essentially similar with no interaction.

Seven of the 28 subjects (4 girls and 3 boys) met the error criterion for each orientation up to 180° . The medians of the correct response times of these subjects at each orientation are shown in Table 3.

Linear regressions of response time on angle of rotation were fitted to these data for each individual subject. The regressions yielded three measures per subject : an intercept, slope and the coefficient of determination, \underline{r}^2 expressing the goodness of fit of the regression. Rejection of the null hypothesis of zero \underline{r}^2 with 5df requires \underline{r}^2 to exceed .568 for rejection at the .05 confidence level. Thus $\underline{r}^2 > .568$ is taken as indicating a linear response time function with increasing angle of rotation. The slopes and the \underline{r}^2 values achieved by the seven subjects meeting error criterion are shown in Table 4. It can be seen from this table that five of the children achieved \underline{r}^2 values

exceeding the critical value.

Of the nine children completing trials for stimulus B and stimulus C only two (one of each sex) satisfied the error criterion for all levels of rotation for stimulus B, and likewise the same two satisfied criterion for stimulus C.

Discussion

As in Experiment 1 stimulus A appeared to be the easiest and percentage of errors increased with angular difference between the two forms. Errors did not exceed the chance level of 50% at the 180° rotation. Errors in excess of 50% would be expected if subjects responded on the basis of matching internal forms, ignoring object orientation. However, the bimodal pattern of errors with angular difference for stimulus B was preserved, indicating comparison of internal structures only. Errors tended to increase with angular difference for stimulus C.

Differences between stimulus A and stimulus C suggest that complexity of the stimulus may affect the child's performance. Differences between stimulus A and stimulus B suggest that differences in task and complexity may alter the method of solution the child adopts.

Also results suggest that there are no sex differences for these particular tasks.

If, following Shepard (Shepard & Metzler, 1971; Cooper & Shepard, 1973) a linear trend of response times with angular separation of stimuli is taken to indicate kinetic imagery then only 5 of 28 children displayed kinetic imagery using the simplest stimuli. Contrary to indications from Experiment 1, these results show that in general, children of this age group can not cope adequately with the rotation task for any of the three stimuli.

However, it was noted that many subjects were able to respond correctly during practice trials which used the stimuli employed in Experiment 1. The discrepancy may be due to the fact that there was a figure-ground contrast of the cream coloured bottle shapes on a wooden table in Experiment 1 whereas the outlined bottles of the test stimuli in Experiment 2 did not appear as solid coloured forms. The outline drawings may not serve as suitable representative bottles for this task.

This experiment used bottle shaped areas of solid colour rather than outline drawings as stimuli for the rotational matching task of Experiment 2.

Subjects

Twenty children (7 girls and 13 boys) with an age range of 5.5 to 6.0 years and a mean age of 5.73 years from a single classroom at Burnside Primary School, Christchurch, participated in this experiment.

Apparatus, Procedure, and Stimuli

The apparatus and procedure of Experiment 2 were used. The stimuli resembled that of Experiment 2 but this time the bottle shapes were coloured yellow and orientations from 0° to 180° in increments of 30° were used. Also only stimulus A was used. The ordering of trials was randomly determined within the constraints applying to Experiment 2, each subject completing 2 replications of all 7 (orientations) \times 2 (same or different) = 14 conditions.

Results and Discussion

Percentage of errors for each orientation are given in Table 5. In accord with results from Experiment 2 the percentage of errors increased with angular difference between the two members of each stimulus pair. Also it can be seen that there is a rapid increase of errors beyond 90° . The criterion of

at least three correct of four trials was used to^{35.} indicate accurate performance. As in Experiment 2 correct response times were pooled over same and different trials. Medians of response times for those subjects meeting the error criterion for each orientation are shown in Table 6. Linear regressions of response time on angle at rotation were fitted to this data and slopes and \underline{r}^2 values are shown in Table 7. As in Experiment 2 the critical value of \underline{r}^2 for rejection of the .05 level of the hypothesis of $\underline{r}^2 = 0$ was used to indicate a linear trend.

Eleven subjects met the error criterion for all rotations up to 180° and all of these exceeded the critical value of \underline{r}^2 (.568). Similarly, three more subjects met the error criterion for all rotations up to 150° and exceeded the critical \underline{r}^2 value of .658 with 4df. An additional subject met the error criterion for all rotations up to 120° but did not exceed the corresponding \underline{r}^2 value of .711 (3df). However this subject plus one other who met the error criterion up to 90° exceeded the critical \underline{r}^2 value of .903 (2df). Three of the remaining four subjects met the error criterion up to 60° but did not achieve appropriate \underline{r}^2 values exceeding .994 (1df). The slopes and \underline{r}^2 values achieved by each subject are shown in Table 7.

Thus 55% of the subjects achieved a linear trend for correct response times with angular separation of stimuli up to 180° while 80% achieved a linear trend

up to 90° , indicating that most of the 5- year olds solved the problems using kinetic imagery.

Differences between the sexes in the number achieving linear trends were tested using the Fisher Exact Probability test. Comparisons of performances separately for the rotations up to 180° and up to 90° indicated that proportions of boys and girls satisfying the joint criterion and therefore displaying kinetic imagery were not significantly different, although Table 5 shows a trend for boys to make fewer errors, and Table 7 suggests that their response times more closely follow a pattern of linear increase with angular separation.

It appears that subjects generally used kinetic imagery to solve the "confusion" trials at the 180° orientation since 55% of the subjects displayed kinetic imagery up to 180° . Of the nine subjects who did not achieve a linear function up to 180° only four had errors exceeding chance level at 180° . These four subjects also had errors exceeding chance level for the 120° and 150° orientation positions which indicates that the 180° trials were not more difficult than either of these orientations. Therefore it cannot be concluded that subjects were tempted to compare the internal structures for the "confusion" trials for stimulus A.

EXPERIMENT 4

This experiment used stimulus B to investigate the effects of a more complex stimulus.

Subjects

Twenty children (16 girls and 4 boys) with an age range of 5.5 to 6.0 years and a mean age of 5.82 years from Avonhead School, Christchurch participated in this experiment.

Apparatus, Procedure and Stimuli

The apparatus and procedure of Experiment 3 were used but trials using the practice stimuli (i.e. the stimuli used in Experiment 1) for both stimulus A and stimulus B were given. The test stimuli consisted of stimulus B and orientations from 0 to 180° in increments of 45°.

Results and Discussion

Only 2 of the 20 subjects (both boys) met the error criterion up to 180° rotation. A sign test was used to compare errors between orientation positions. Table 8 shows comparisons between all pairs of orientations. In this table "equal" indicates the number of subjects who had equal numbers of errors for both orientation positions being compared, "n" indicates the number of subjects having differences

between numbers of errors, " ∞ " indicates the number of subjects who had differences but not in the direction expected for comparison of internal structures only, and "p" indicates the two-tailed probability value that there is no difference between the errors of orientation positions being compared.

Differences between the number of errors at 45° and 90° orientations, and likewise at 90° and 180° were not significant. Significantly more errors were made at both 45° and 135° than at 90° and significantly more errors were made at both 45° and 135° than at 180° . These results are illustrated in Table 9 which shows the number of children reaching error criterion at each orientation.

Neither of the two children meeting error criterion achieved the appropriate r^2 value indicating an absence of a linear trend of response time with angular separation of stimuli.

In general results strongly indicate that kinetic imagery of rotation was not being used to solve the task. As suggested in Experiment 1, children compared only the internal structures of the stimuli in this case, ignoring the orientation of the whole form.

There were not enough boys in this experiment to isolate any sex differences.

Comparison of Experiments 3 and 4

The Fisher Exact Probability test was used to compare the numbers meeting the joint criterion up to 180° rotation for those participating in Experiments 3 and 4. Results showed a significant difference in favour of those participating in Experiment 3 ($p = .008$ two-tail). This indicates that the method of solution varied with the nature of the task and the stimulus used. However, as 65% of the subjects in Experiment 3 were boys whereas only 20% of those in Experiment 4 were boys, and boys compared favourably with the girls in Experiment 3 (although not significantly) these results may, in part, be due to the differential sex composition of the groups. A Chi Square test was used to compare the performance of girls only in the two experiments, this yielding a significant effect ($\chi^2(1) = 4.59, p < .01$ two-tail) in favour of the girls participating in Experiment 3. Thus it may be concluded that at least for girls the differences between the task and stimuli in the two experiments affected the extent to which kinetic imagery was used as a method of problem solution.

EXPERIMENT 5

This experiment used stimulus A and 4-year old children to compare the performance of these children with that of the 5-year olds in Experiment 3.

Subjects

Twenty children (10 of each sex) aged between 4.5 and 5.0 years with a mean age of 4.76 years participated in this experiment. Five of each sex were chosen randomly from McKenzie and Avonhead Kindergartens, Christchurch. These particular kindergartens were chosen because they fed into the schools used in Experiments 2, 3 and 4. This was to control for possible affects of socio-economic status.

Apparatus, Procedure and Stimuli

The apparatus and the procedure used in Experiment 3 applied here also.

Results and Discussion

Percentages of errors for each orientation are given in Table 10. The percentage of errors increased with angular difference between the two members of each pair of stimuli up to 180° . Median times of correct responses for those subjects meeting the error criterion applied in Experiment 3 are shown in Table 11. Linear regressions of response time on

angles of rotation were fitted to this data for each subject individually as in Experiment 3. Three of the 20 subjects met the error criterion for all rotation positions up to 180° . All achieved \underline{r}^2 values exceeding the critical value for rejection of the null hypothesis of $\underline{r}^2 = 0$ with 5df at the .05 level (.568). Two subjects met the error criterion for all rotation positions up to 120° but did not achieve the appropriate critical value of \underline{r}^2 with 4df (.658). However, one of these subjects plus three of five others who met the error criterion up to 90° rotation achieved an \underline{r}^2 value exceeding the critical level with 3df (.711). An additional five children met the error criterion for all rotation positions up to 60° but none of these reached the appropriate critical \underline{r}^2 value with 1df (.994). The remaining five subjects did not meet the error criterion for all rotation positions up to 60° and one of these did not appear to understand the task instructions. The slopes and the \underline{r}^2 values resulting from the above computations are given in Table 12.

In general these results indicate that children of this age group can not use kinetic imagery to solve the experimental task. The fact that 40% of the children could solve the problems up to 90° indicates that younger children may be able to cope with small differences in orientation only.

Percentage of errors increased well beyond chance level at 150° and 180° rotation positions but only for girls. It appears that only the internal structures were being compared for the "confusion" trials and this was generalized to the 150° position.

Differences between the sexes in the number of children satisfying the error criterion and achieving acceptable values of \underline{r}^2 were tested using the Fisher Exact Probability Test. Comparisons of performances separately for the rotations up to 180° and up to 90° indicated that proportions of boys and girls satisfying the joint criterion and therefore displaying kinetic imagery were not significantly different although visual examination of Table 10 suggests a tendency for boys to make fewer errors beyond 90° .

Comparison of Experiments 3 and 5

Numbers of 4- and 5- year olds meeting error criterion and achieving appropriate \underline{r}^2 values (i.e. displaying kinetic imagery) were compared separately for orientations up to 90° and 180° with stimulus A. Using the Fisher Exact Probability test a clear age difference was found in favour of the older group of children ($p = .048$, two-tail for rotations up to 90° and $p = .018$, two-tail for rotations up to 180°). These results imply that the ability to use kinetic imagery to solve this type of problem develops

significantly from the ages 4 to 5 years for this particular population.

GENERAL DISCUSSIONInconsistencies With Piaget's Theory

Insofar as the Shepard paradigm is an adequate measure of kinetic imagery, findings from Experiment 3 clearly contradict the claim that kinetic imagery first emerges at approximately 7 to 8 years of age (Piaget & Inhelder, 1971). Results from this experiment showed that over half of the 5-year olds were capable of mentally rotating the stimuli used the maximum angular distance of 180° . Although Piaget and Inhelder's concept of *décalage* may account for a certain amount of variability between ages at which the phenomenon is first observed, this explanation becomes extremely tenuous when considering an age gap of 2 to 3 years. Moreover, Piaget and Inhelder's (1971) own findings that some 4 and 5-year olds could solve kinetic imagery problems were interpreted as a result of static reproductive imagery, not *décalage*. This interpretation is inadequate for the present findings because it does not account for the linear relationship between reaction time and the angular separation between stimuli. In addition, results of Experiments 3 and 5 indicate that development is gradual since numbers of children displaying kinetic imagery increased with decreasing angular distances

between stimuli and the performance of 5-year olds^{46.} was superior to that of the 4-year olds (more so for rotations up to 180° than those up to 90°). A greater number of rotation positions tested may show linear trends for most 4-year olds for angles of rotation less than 90° since most 4-year olds met the error criterion for correct responses up to 60° rotation but did not achieve a linear trend for the required proportion of the variation which may be due to the high critical value of \underline{r}^2 applying with a single degree of freedom.

Since the procedure did not involve motor manipulations of the stimuli by the child, these findings also contradict a second claim of Piaget, i.e. that the preoperational child cannot produce dynamic visual representations (internally) without motor activity involving the events to be represented (Piaget, 1962).

Methodology : A Possible Source of Disagreement

Although differences in response measure of the present study and Piaget's work may account for the conflicting results there were also differences in instructions given to the child. In the present experiment children were shown rotations of the stimuli in order to explain the problem, thus suggesting a method of solution. This seemed to be

necessary for children to understand the task. Piaget and Inhelder's (1971) procedures involved no solution suggestions and therefore involved greater demands upon the child. Thus children under 7 years might have exhibited kinetic imagery on Piaget and Inhelder's tests, had they first been given clues as to how the task might be performed.

However, whether tested for or not, all work involving the study of kinetic imagery to date confounds the development of kinetic imagery with the ability to understand the abstract concept of the tasks, since all those who have used kinetic imagery to solve the task must first have understood the nature of the problem. Thus conclusions must remain specific to the task employed.

Effects of Stimulus and Task

Results from Experiment 2 compared with those of Experiment 3 showed that 5-year olds generally could not mentally rotate outlined figures but most used mental rotation to solve the experimental task when the outlined figures were filled in and appeared as a solid two-dimensional shape. This observation is in accord with the work of Vernon (1976) which implies that in early childhood, perception of form is not very well focussed or accurate. Differences in performance with representation of the stimuli may be restricted to outlined forms versus solid two-

dimensional forms or may reflect that the more abstract and symbolic the stimulus becomes the poorer the child's performance. The literature shows that this is not the case for adult subjects: there was essentially no difference in performance using two-dimensional random polygons (Cooper, 1975) or three-dimensional nonsense shapes composed of wooden blocks (Metzler and Shepard, 1974; Shepard and Metzler, 1971). Further research is needed involving three-dimensional stimuli and children as subjects. Performance may not only vary with representation but also with relative meaningfulness of the stimuli. Milk bottles labelled with stars was a contrived situation with which the child had no previous experience. While the nonsense situation was employed to control for effects of varying past experience this aspect detracted from the meaningfulness of the stimuli. Again, further research is needed in this area.

Results from Experiment 4 using 4-pointed stars showed that 5-year olds were inclined to compare the internal structures of the static figures rather than mentally rotate them if tempted to do so by "confusion" trials. However the 5-year olds participating in Experiment 3, involving a simpler internal structure (3-pointed stars), resisted this temptation. Thus it appears that subjects ignored

the external structure of the stimuli only when the internal structure was made more complex for the "confusion" trials. The surface implication of this finding is that the complexity of the stimulus, as defined by Cooper (1975), is an important variable determining whether or not kinetic imagery is used for this age group. However, in this study, differences in symmetry between Stimulus A and Stimulus B were not controlled. While Stimulus A was symmetrical about the vertical axis as was Stimulus B, the internal structure of Stimulus B was also symmetrical about the horizontal axis. Indeed, Wallace's (1978) findings implied that when solving the Shepard task, children aged 4 to 9 years mentally rotated asymmetrical letter-like forms but did not mentally rotate symmetrical letter-like forms. Presumably these were symmetrical about either the horizontal or vertical axis. In a separate experiment Wallace found that adults mentally rotated symmetrical figures. As the 5-year olds participating in Experiment 3 of the present study generally did appear to mentally rotate the vertically symmetrical stimuli, the discrepancy between the two studies may be due to the effects of the external structure i.e. the external structure may have encouraged mental rotation using a vertically symmetrical internal structure, but may not have been sufficient to induce this method of

solution using the doubly symmetrical internal structure of Stimulus B.

Results of independent studies indicate, that in general, children under about 6 years have more difficulty than older children and adults in perceiving precisely the exact characteristics of complex figures and inter-relationships with the parts of these to each other and to the whole figure (Vernon, 1976). Thus the fact that stimuli consisted of both an external and internal structure may account for some of the children's inability to solve the task. However, a specific understanding of the results awaits further research which tests for separate effects of symmetry and complexity.

Sex Differences

No significant sex differences were found using the test adopted (The Fisher Exact Probability Test) although visual examination of the data of Experiments 3 and 5 reveals a slight difference in favour of males. This suggests that more trials and a more powerful test may show a tendency for male superiority. However, this tendency is not very great, if it exists at all, and is unlikely to have any significant effect on the large differences found between results of Experiment 3 and those of Experiment 4.

Experience

One factor which may play a crucial role in the development of kinetic imagery is experience. This has been shown to affect the development of other "operational" skills (see Adjei, 1974 cited in Buck-Morss, 1975; Nelson, 1975; Price-Williams, 1968, cited in Buck-Morss 1975, 1976; Price-Williams, Gordon and Ramirez, 1974, cited in Buck-Morss, 1975). Also, a "time-lag" in performance on Piaget's tests occurs in children of non-industrialized countries and in children from homes of lower socioeconomic status in industrialized countries (Buck-Morss, 1975). As an explanation, Buck-Morss proposed that this was due to the experience of those with lower socioeconomic industrialized backgrounds and non-industrialized backgrounds being limited to a realm of a concrete immediacy.

Observations of Goodnow (1969) showed that this pattern may include kinetic imagery. Specifically, Goodnow noted that children from non-technological cultures have the greatest difficulty with Piagetian tasks involving "mental shuffling" i.e. kinetic imagery. Moreover, she pointed out that cultures differ greatly among themselves in the practice they provide in mental as against physical manipulations of objects, and speculated that there

are "almost certainly" socioeconomic status differences in restraints on unnecessary or impulsive action.

Since the present experiments included children from schools and kindergartens in a middle to upper class area only, results cannot be generalized beyond this population as possible variations in experience with socioeconomic status may affect the development of kinetic imagery.

Also, it is tentatively suggested that the large difference between 4 and 5-year olds ability to solve the experimental task using kinetic imagery may be related to the introduction of the school experience, i.e. without any formal education a child would normally be required to focus on, comprehend, and distinguish between varying positions of rotated objects less frequently than a child attending school (e.g. learning to tell the time and learning to distinguish between alphabetical or numerical characters which have identical physical forms but differ in orientation). This is particularly so for objects rotated beyond 90° , since in day to day living objects are seen more frequently to rotate to a maximum of 90° , due to gravitational laws, (e.g. an object falling over on a flat surface and then being righted).

Thus, the development of kinetic imagery may be more flexible and more dependent upon environment than Piaget and Inhelder (1971) have proposed. However these are merely speculations - again further research is needed.

Conclusion

Overall, results of this study indicate that kinetic imagery develops gradually and that this development begins long before Piaget and Inhelder's estimate of 7 to 8 years. Also, whether kinetic imagery is used by young children depends on the nature of the stimulus and task. Thus kinetic imagery may be regarded as a complex set of processes which increase in degree of sophistication over a number of years; its rate of development inter-related with that of perceptual skills and possibly affected by experience.

TABLE I

Percentage of Errors at Each Orientation
for Each Age Group and Stimulus - Experiment 1.

Angular Separation Between Stimuli

Age Group	Stimulus	0°	45°	90°	135°	180°
4.75 yrs. (n=7)	A	0	10	29	58	88
	B	0	94	4	86	4
	C	0	10	25	75	50
5.0 yrs. (n=4)	A	0	15	36	60	80
	B	0	92	8	92	8
	C	0	12	28	46	52
5.75 yrs. (n=6)	A	0	0	10	14	14
	B	0	81	4	81	4
	C	0	4	16	21	24

TABLE 2

Percentage of Errors at Each Orientation
Experiment 2

Angular Separation Between Stimuli

Stimulus	0°	45°	90°	135°	180°
Stimulus A					
Boys (n=14)	0	12.4	30.1	45.0	64.7
Girls (n=14)	0	8.0	22.2	50.2	42.8
Total (n=28)	0	10.2	26.1	47.6	53.4
Stimulus B					
Boys (n=5)	0	40.7	0	29.9	0
Girls (n=4)	0	48.8	0	50.1	12.6
Total (n=9)	0	44.4	0	38.9	5.6
Stimulus C					
Boys (n=5)	7.2	43.2	36.7	44.28	0
Girls (n=4)	3.6	20.9	29.0	53.2	11.3
Total (n=9)	5.6	33.3	33.3	48.2	5.0

TABLE 3

Medians of Correct Response Times (in seconds)
 for 5-year old subjects meeting the error
 criterion up to 180° with Stimulus A -
 Experiment 2

		<u>ANGLE OF ORIENTATION</u>				
		0°	45°	90°	135°	180°
Girls	S1	2.0	3.4	4.0	4.5	5.6
	S2	1.8	4.3	3.8	4.0	3.7
	S3	1.7	2.7	2.9	2.8	4.0
	S4	2.2	4.2	3.7	4.2	3.6
Boys	S1	1.8	2.0	2.2	2.3	2.5
	S2	1.7	1.9	2.3	3.5	3.4
	S3	1.8	1.9	2.8	2.5	3.3

TABLE 4

Slopes and \underline{r}^2 values for the Individual Response Time Functions of 5-year olds meeting the Error Criterion for all Orientations up to 180° with Stimulus A - Experiment 2.

		Slope	\underline{r}^2
Girls	S1	.018	.968
	S2	.008	.313
	S3	.010	.828
	S4	.006	.292
Boys	S1	.004	.990
	S2	.011	.883
	S3	.008	.824

TABLE 5

Percentage of Errors for 5-year olds at Each
Orientation using Stimulus A - Experiment 3

		Angle of Orientation						
		0 ^o	30 ^o	60 ^o	90 ^o	120 ^o	150 ^o	180 ^o
<hr/>								
Girls								
n=7	0	3.6	3.6	25.0	42.9	46.4	46.4	
<hr/>								
Boys								
n=13	0	0	5.8	5.8	11.5	19.2	25.0	
<hr/>								
Total								
n=20	0	1.3	5.0	12.5	22.5	28.8	32.5	

TABLE 6

Medians of Correct Response Times (in seconds) for
5-year olds Meeting Error Criterion for each
Orientation Using Stimulus A - Experiment 3.

		<u>ANGLE OF ROTATION</u>						
		0°	30°	60°	90°	120°	150°	180°
Girls	S1	1.95	2.3	2.4	3.2	2.9	2.7	3.8
	S2	2.0	2.8	3.0	3.0	3.65	3.4	3.3
	S3	1.75	1.8	2.0				
	S4	1.6	1.9	2.1				
	S5	1.75	2.25	2.3				
	S6	2.85	2.85	2.9	3.17	3.6	4.7	4.9
	S7	1.85	2.2	3.2	3.15	4.0	4.2	
Boys	S1	1.95	2.2	2.3	2.45	3.35	3.7	3.8
	S2	1.9	2.1	2.25	2.7	3.25	3.3	3.2
	S3	2.2	2.15	2.25	2.2	2.5	3.6	3.5
	S4	1.5	1.7	2.4	2.6	2.3		2.95
	S5	1.85	2.1	3.15	3.5	3.85	4.7	5.0
	S6	1.55	1.95	2.05	2.2	2.25	3.2	3.8
	S7	1.9	2.35	3.25	2.95	3.35	3.65	5.05
	S8	1.45	1.75	1.5	2.7	2.0	3.2	
	S9	2.0	2.15	2.9	3.65	4.1	4.5	4.8
	S10	1.6	1.8	2.35	2.6	2.55	3.35	
	S11	2.6	2.9	3.75	3.35	3.45	4.35	4.2
	S12	1.3	1.45	1.8	2.1			
	S13	2.7	2.77		4.7			3.75

TABLE 7

Slopes and \underline{r}^2 Values for the Individual Response Time Functions of 5-year olds Meeting the Error Criterion for all Orientations up to the Level Stated for Stimulus A - Experiment 3.

		Children Meeting Criterion up to 180 ^o	
		Slope	\underline{r}^2
Girls	S1	0.008	0.730
	S2	0.007	0.691
	S6	0.013	0.847
Boys	S1	0.011	0.923
	S2	0.009	0.902
	S3	0.008	0.722
	S5	0.018	0.978
	S6	0.011	0.861
	S7	0.014	0.849
	S9	0.017	0.976
	S11	0.009	0.792
		up to 150 ^o	
Girls	S7	0.016	0.948
Boys	S8	0.010	0.658
	S10	0.011	0.921
		up to 120 ^o	
Boys	S4	0.008	0.694
		up to 90 ^o	
Boys	S12	0.009	0.977
	S4	0.013	0.941
		up to 60 ^o	
Girls	S3	0.003	0.923
	S4	0.008	0.987
	S5	0.009	0.818
Boys	S13	Did not meet error criterion for 60 ^o	

TABLE 8

Comparisons Between all Pairs of Orientation
Positions Using Sign Tests for 5-year olds
Using Stimulus B - Experiment 4.

	90°	135°	180°
45° =	3	11	5
n	17	9	15
χ	2	2	0
p	.002	.180	<.008
90° =		1	8
n		19	12
χ		2	5
p		<.004	>.5
135° =			4
n			16
χ			2
p			.004

* All p values are 2-tail.

TABLE 9

Number of 5-year olds Satisfying the Error
Criterion for each Orientation Using Stimulus B
- Experiment 4.

Angle of Rotation				
0°	45°	90°	135°	180°
<hr/>				
20	5	19	3	17
<hr/>				

TABLE 10

Percentage of Errors for 4-year olds at each
Orientation Using Stimulus A - Experiment 5.

		Angle of Orientation						
		0°	30°	60°	90°	120°	150°	180°
<hr/>								
Boys								
n*	=9	0	5.5	25	36	50	47.2	55.5
<hr/>								
Girls								
n	=10	0	2.5	15	37.5	60	80	80
<hr/>								
Total								
n	=20	0	4.0	19.7	36.8	55.2	64.5	68.4
<hr/>								

* One boy could not understand the instructions.

TABLE 11

Median Reponse Times (in seconds) for 4-year
olds Meeting Criterion for Each Orientation
Using Stimulus A - Experiment 5.

		<u>ANGLE OF ROTATION</u>						
		0°	30°	60°	90°	120°	150°	180°
Girls	S1	2.4	2.6	3.2				
	S2	2.3	2.4	3.2	3.5			
	S3	2.35	2.45	2.9				
	S4	1.5	1.6					
	S5	2.3	2.35	3.6		4.3		
	S6	1.7	1.75	2.1				
	S7	2.15	2.8	2.45	2.8			
	S8	2.25	2.5	3.0	3.2	2.8		
	S9	1.75	2.5	3.8	5.2			
	S10	1.85	1.65	2.3	2.45	2.35		
Boys	S1	1.9	2.05	2.4	2.5	2.85	3.5	3.7
	S2	1.8	2.15	2.8				
	S3	2.65	3.1		5.2			
	S4	2.35	2.9	3.6	4.3			
	S5	1.75	1.6					
	S6	2.75	2.35	2.95	2.85		4.6	
	S7	2.15						
	S8							
	S9	2.9	2.85	3.45	3.2	6.2	6.5	4.9
	S10	1.9	2.2	2.25	2.95	2.9	3.6	3.3

TABLE 12

Slopes and \underline{r}^2 values for the Individual Response Time Functions of 4-year olds Meeting the Error Criterion for all Orientations up to the Level Stated for Stimulus A - Experiment 5.

Those Meeting Criterion up to 180°		Slope	\underline{r}^2
Boys S1		0.010	0.958
S9		0.019	0.621
S10		0.009	0.886
up to 120°			
Girls S8		0.006	0.559
S10		0.006	0.664
up to 90°			
Girls S8		0.011	0.973
S10		0.008	0.711
S2		0.015	0.922
S7		0.005	0.434
S9		0.039	0.983
Boys S4		0.022	0.997
S6		0.003	0.195
up to 60°			
Girls S1		0.013	0.923
S3		0.009	0.881
S5		0.022	0.779
S6		0.067	0.842
Boys S2		0.017	0.971

FIGURE 1

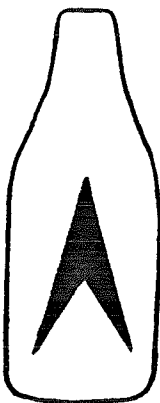
Stimuli

"Standard" and
"Identical" Forms

"Different"
Form

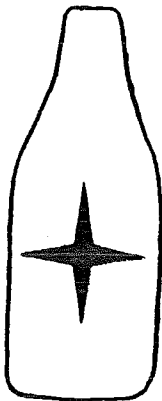
Stimulus (A)
(3-point) star

The star is
rotated 180°



Stimulus (B)
(4-point) star

The star is
rotated 45°



Stimulus (C)
(5-point) star

The star is
rotated 72°

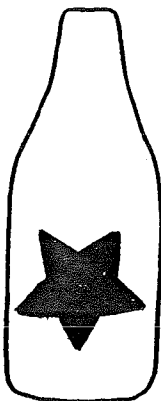
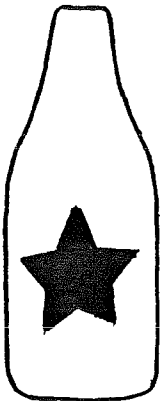
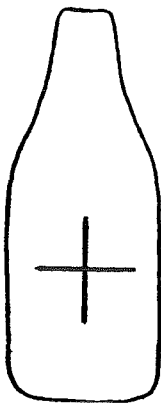
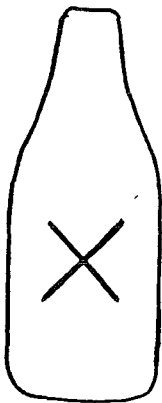


FIGURE 2

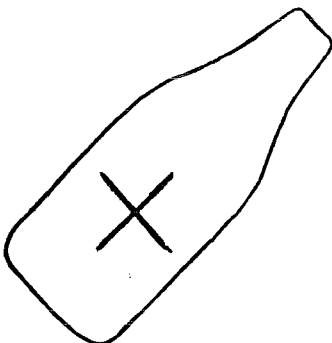
Examples of "Confusion" Trials with
Stimulus B.



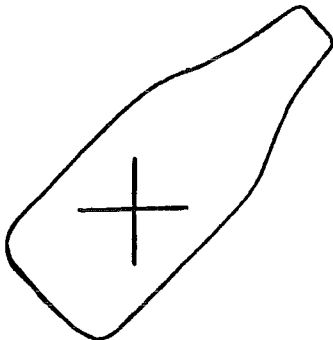
"Standard" and
"Identical" Forms
(i)



"Different"
Form
(ii)



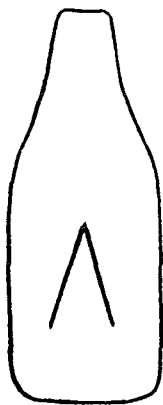
"Identical" form
rotated 45°
(iii)



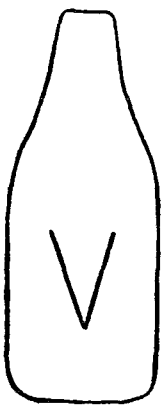
"Different" form
rotated 45°
(iv)

FIGURE 3

Examples of "Confusion" Trials
with Stimulus A.



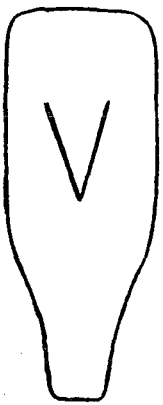
"Standard"
form



"Different"
form



"Different"
form rotated
180°



"Identical"
form rotated
180°

ACKNOWLEDGEMENTS

I wish to record my gratitude to the people who helped to make the writing of this thesis a possibility.

First I would like to thank my supervisor, Paul Russell, for his valuable criticisms and statistical advice, as well as his encouragement throughout the year.

Also, my thanks are due to the technician, Glen Lewis, who built the experimental apparatus.

I would like to express my appreciation to the Canterbury Education Board, the Kindergarten Association and the principals, teachers and pupils of all schools and kindergartens concerned for their co-operation with the data collection.

Finally, special thanks must go to Jocelyn Clapp for typing this work and to Mark Morris for bearing the brunt of my pre-occupation during the latter stages of completion.

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